VIDEO QUALITY ASSURANCE ACROSS IP NETWORKS

Martin KAPA, František JAKAB
Department of Computers and Informatics, Faculty of Electrical Engineering and Informatics, Technical University of Košice, Letná 9, 042 00 Košice, Slovak Republic, tel.: +421 55 602 2553

ABSTRACT

We have witnessed a significant increase of the user requirements in the field of multimedia services. Therefore, service providers are forced to assure specific level of quality to earn the trust of theirs customers. QoE together with video quality have become essential terms in regard of designing any video-providing services. However, it was proved that current methods in the user-centered service design are inaccurate in considering resulting user experience and perceived quality of video streams. In this paper we are outlining actual state of art and future challenges in this particular problematic. All of which results in introducing of our new designed concept of QoE prediction model based on deep analysis and understanding of network behaving represented by sets of statistical data.

Keywords: *video quality, user experience, QoE, QoS, Bayesian networks, prediction model*

1. INTRODUCTION

In the recent years the field of Traffic Monitoring and Video Quality Measurement has been one of the main interests of active research within the network community oriented on multimedia services. It is caused by a change in the world of entertainment where we are currently trying to support vivid methods of video content delivery (e.g., video-on-demand, iptv, video streaming). The industry is considered relatively young, but the viewers demand high quality and flawless experience. To support these requirements, service providers have to have a comprehensive service assurance solution in order to achieve desired expectations of continuous high-quality viewing experiences.

With the emerging of new Internet content types current monitoring and measurement standards has become insufficient. The multimedia content consumed by users has significantly increased and users are constantly downloading video streams, using different applications and even sharing their own video streams. All of which become highly sensitive on traffic states in terms of network delay and level of packet loss. Therefore, ties between content and internet providers become much more important than just considering specific network parameters. It results in re-setting of view on evaluation of service quality. We moved from evaluation of the content or even network to emphasis on degree of satisfaction achieved by the users. This was supported by emerging of new standards capable to assess such user satisfaction, for example Quality of Experience (QoE).

QoE as a young assessment technique requires the definition of a new set of metrics, which would be capable to evaluate the user satisfaction. This is considered as a main challenge cause of subjective aspects, e.g., experience of the user, or mental state of the user, that play a role in the final assessment.

To better understand the new challenges in providing multimedia services and video quality assurance, we overview the current approaches and possibilities of user experience prediction.

The paper is structured as follows. We set up the foundations for our concept in section ASSESSMENT OF QOE, where we describe important terms used while evaluation of user experience. In followed section we come with future challenges for this field and we closely outline the process of creation future QoE evaluation frameworks. The rest of the paper deals with close description of our concept. Finally, section DISCUSSION/CONCLUSIONS concludes the paper and highlights future research directions.

2. ASSESSMENT OF QOE

There are several techniques to measure QoE, but two main approaches has recieved significant attention from industry and research groups, refered as Content Inspection/Artifact-based Measurement and Network-based Measurement [1]. The first mentioned orients on decoding of video content, followed by calculation of the quality level by using QoE metrics that range from simple comparison schemes to much more sophisticated solutions based on Human Visual System (HVS) [2], while the second approach is trying to predict quality level based on information gathered from packet and network inspection [3].

In the content inspection, subjective and objective methods are used to find distortion in multimedia streams. Subjective Quality Assessment is based on real group measurements of perceived quality, although it can not be accurately measured or computed. What is caused by the fact that the quality values change with every particular viewer and it supports the claim that the results are mostly influenced not just by the quality itself, but also by specific viewer's state of mind of. Standards that orient on subjective quality assessment of video and audio quality can be found in ITU-R Rec. BT.500-11 [4] and ITU-T Rec. P.910 [5].

On the other hand compared to the subjective quality assessment, objective quality assessment is a technique that is defined as a mathematical model for prediction of the subjective quality assessment. It is build on metrics that can be automatically evaluated. These metrics then are divided into three groups on account of availability of a reference video (Full-Reference (FR), No-Reference (NR), Reduced-Reference (RR)). The FR method uses the reference video to measure the quality degradation of the distorted medium. The whole process is done in two steps, the first step calculates the errors between original and distorted images and the second one has to pool the particular errors to a global quality assessment [6]. The NR evaluates perceptual quality only based on the distorted medium, while RR is a hybrid between FR and NR metric in terms of the reference information, where only a set of features from the reference medium is needed instead of the whole medium itself.

3. CHALLENGES FOR PROVIDING OF THE HIGH-LEVEL QUALITY OF EXPERIENCE

In the recent years video and multimedia services have built their position as the future source of information not just an instrument of entertainment. Therefore, with the increasing importance of the user mobility the corresponding multimedia services need to be highly reliable to earn the trust of its customers.

This is why we need precise assessment methods and frameworks to guarantee a specific level of user experience. In order to archive this goal we firstly need to consider which parameters have influence on degradation of user experience and quality of multimedia content. This has partially been done with signalto- noise ration (SNR), peak signal-to-noise ration (PSNR) or bit error rate (BER). However, the latest measurements shown that they do not correlate well with quality perceived by an end-user [7].

To assure excellent quality of user experience, service providers have to have powerful end-to-end, fault-management systems for continuous monitoring of specific service and network performances. One of the options to assure acceptable video delivery is trying to measure the video source quality in compare to well known industry standards and to measure specific network parameters like bandwidth, delay, packet loss, which can have high impact on resulted user experience. Besides that, we should also collect statistics about network utilization, where we would be able to track minimum and maximum overall network utilization. High utilization is one of the indicators of network congestion, which results from queue behavior in one of the network components.

The range of video parameters is much wider, but it is important to collect data about parameters like bit rate, video resolution, frame rate and codec. Bit rate represents the number of bits processed during one time unit. Video resolution is a size of a video image measured in pixels, where the numbers represent horizontal and vertical resolution. Frame rate specify a frequency at which the streaming device produce images that are called frames. Video codec is a software used for encoding and decoding of a digital data stream.

4. CURRENT RESEARCH

The popularity of the QoE is increasing and there are lots of research groups orienting on objective and subjective QoE evaluation. However, objective quality assessment methods have several limitations and many researchers have recently been trying to develop hybrid solutions. One of the promising solutions is a tool that is called Pseudo-Subjective-Quality Assessment (PSQA) [8] that has been developed by the project Dionysos at the IRISA/INRIA of Rennes. This approach measure the quality of a video sequence at the receiving end, in a way that is close to the human observations in a real-time. Another approach [9] is based on a prediction model, which is built using ML (Machine Learning) techniques that were successful in building prediction model from a set of training data acquired by a limited-sized initial subjective test. In [10] they presented design and experimentation of QoEScope for the management of enterprise IP service systems with a client-server structure. QoEScope integrates scalable end-to-end probing, adaptive learning of user-perceived service quality, accurate and robust topology inference, and automatic root cause analysis into a single QoE management solution.

Besides that, there are approaches based on protocol extensions. In [11] they propose an extension to RSVP (Resource ReSerVation Protocol) that enables the dynamic change of reservations. The change of reservations takes place in a situation of network congestion, when HD video streaming application changes its demand for network resources. However, this approach was tested only in the emulated environment.

5. FUTURE QOE ASSESSING TECHNIQUES

The view on user experience assessing techniques has dramatically changed. Current approaches do not provide accurate results, all of which are caused by inadequate designing process and misunderstanding of the QoE problematic. While designing future techniques/standards we have to bear in mind steps like Data Acquisition, Metric Selection and Results Analysis. To ensure particular level of user satisfaction every assessment platform needs to collect big amount of data. In the case of QoE those data should be acquired as close to the application users as possible to provide accurate estimation of perceived quality. On top of that, we have to think about what kind information we have to collect, where in our network we want to collect them and how we will realize the acquisition.

The next step is to select right metric. It is really important to invest time into deep research among different metrics, because this selection has critical impact on resulted assessment accuracy. Choosing right metric also depends on what type of assessment we are going to realize. In real-time assessment platform we can not count on availability of original transmitted data. This implies that FR technique would not be used and we should manage it with only RR or NR metrics. Therefore, our accuracy would be bounded, mainly when NR metrics is used.

Table 1 Level of quality in MOS

MOS	Quality	Impairment
5	Excellent	Imperceptible
4	Good	Perceptible, but not annoying
3	Fair	Slightly annoying
2	Poor	Annoying
1	Bad	Very annoying

The last step is to properly analyze our acquired data and decide whether the user is satisfied or not. The level of satisfaction is usually defined by MOS (Mean Opinion

Score). We can define it as a number in range between 1 and 5 used to express level of the quality in multimedia (audio, VoIP or video) [Tab. 1]. MOS for voice quality is standardized in ITU-T R. P.800 [12]. In general, it is accepted that the lower threshold when user is satisfied with the service is a MOS value of 3. Nevertheless, MOS was derived from different metrics, which often do not consider all the necessary factors for a complete assessment.

6. QOE PREDICTION MODEL

As we have already mentioned the use of multimedia services has been growing up in the recent years, and the user perceived quality is one of the most important feedback factors for any service providers. Quality monitoring has surely become critical for the success in this field.

Therefore, the purpose of our current research is oriented in designing of the concept for user experience prediction. That has proved itself as one of the newest approaches for accurate measurement of perceived video quality. Unlike only QoS measurements that are performed only at the transmission paths of a network design. QoE assessment involves several analysis, like analysis of the communication paths and video quality perceived by the user, as presented in [Fig. 1].

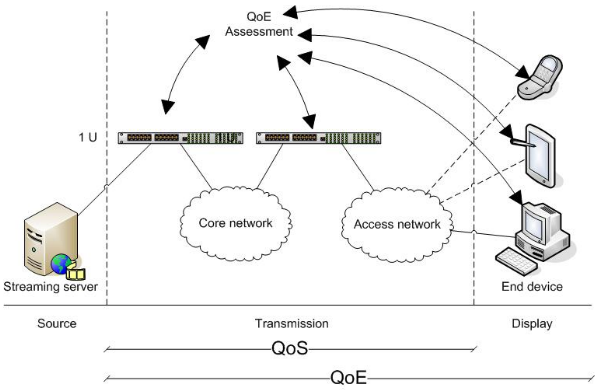

Fig. 1 Real implementation of QoE assessment model

6.1. System overview

In the previous sections we described the differences among current solutions of QoE assessment and we also outlined the challenges for future development. In [Fig. 2] we describe the block scheme of our concept and in behalf of our target to predict user experience, our system consists of four main parts (streaming server, network parameters evaluation, video parameters evaluation, Bayesian network model). The difference of our solution is that we extend previous approaches by monitoring and storing of statistical information about video and network parameters and resulted levels of MOS. Our model is eventually using this knowledge to predict the results of subjective assessment specified by MOS.

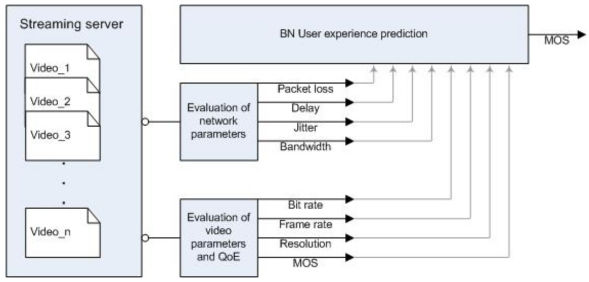

Fig. 2 System overview

In the future we are considering extending this model by objective quality assessment, through which we would be able to monitor an amount of motion and image clearness in video sequence. With these improvements we would provide even more accurate results.

6.2. BN based prediction model

During the designing process of our model we decided that it would be based on BN(Bayesian Network) mostly because of its ability for testing hypotheses concerning the relationship between systems variables and ability to predict probability of a future behaving of system/service on behalf of knowledge gained from the past. BNs are known as belief networks and they belong to the group of probabilistic graphical models. These models are mostly used to represent knowledge about a specific uncertain domain. The graphical representation of BNs consists of nodes and each node in the graph resents a random variable, while the edges between the nodes represent probabilistic dependencies among the corresponding random variables.

The scheme of our model and is divided into three main parts, in the first part we use variable named TypeOfVideo and this variable has three states (high, medium and low) and it is defining three types of video quality.In the second part we can see variables that are defining parameters directly influenced by particular video (Resolution, BitRate) or variables that are defining network condition (PacketLoss). Resolution is defining the resolution of the video stream (D1, CIF, QCIF), BitRate is defining the number of Kbits per second (High: 800-1200Kbps, Medium: 300-800Kbps, Low: 50-300Kbps) and PacketLoss defines the amount of lost packets (VeryHigh: 3.0-5.0%, High: 1.8-3.0%, Medium: 0.8-1.8%, Low: 0.2-0.8%, VeryLow: 0.0-0.2%) and the last part has only one variable that specified the resulted user experience.The inputs into the model are the values of particular parameters and the output is the probability that the user experience is in specific level of MOS, the more data it gets the more accure the results would be.

6.3. Empirical study of user sensitivity

It is not always easy to describe and measure all the events by mathematical models. From philosophy we are able to utilize empiricism defined as a theory of knowledge raised from evidence gathered via sense experience. This method shows some level of inaccuracy. However, in re-

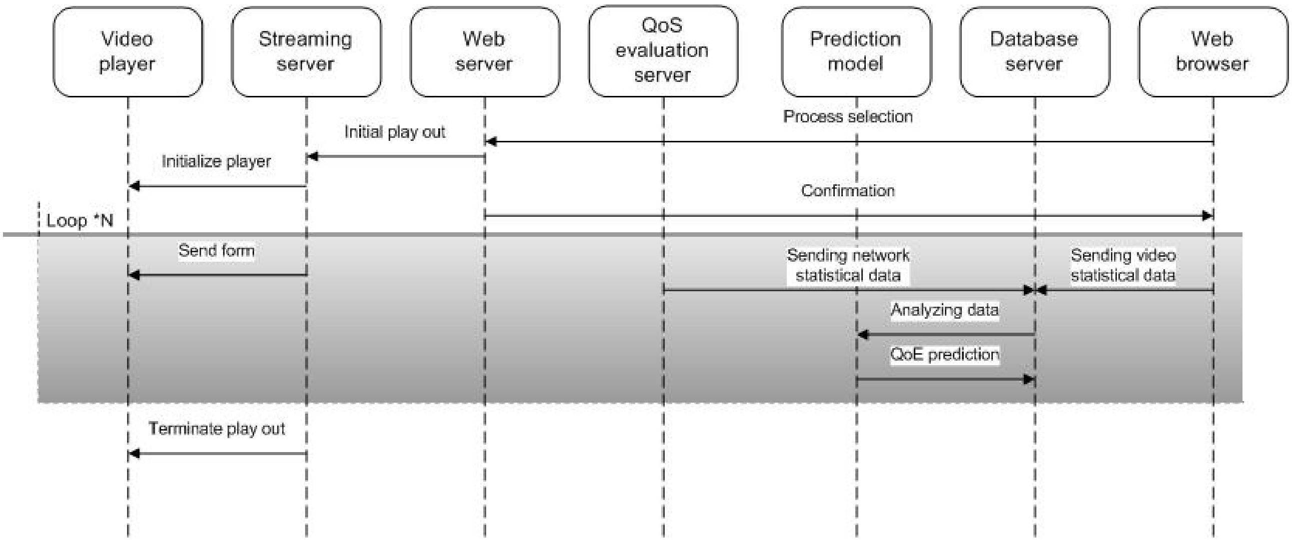

Fig. 3 Sequence diagram

gard of complex systems and services it is one of the best methods how to describe them. It is caused by the fact that highly complex systems are not able to be modeled in detail, but rather with some level of abstraction.

Today there is still unclear how people react on different types of erors while experiencing video streaming. The results are very diverse and people are differently sensitive. However, until now this sensitivity has not been investigated systematically. Therefore, it is an open question when it is justified to count with lower or higher user sensitivity. Based on this observation, we plan a controlled experiment and investigate the relations between values of video & network parameters and resulted perceived quality.

The outcomes of this study would be used as a basic set of knowledge used to teach the dependencies among specific parameters in our prediction model.

6.4. Process flow in QoE prediction model

Our solution combines service providing and real-time evaluation of QoE based on client-server communication, as presented in [Fig. 3]. The whole process is initialized by choosing specific video sequence through a web browser at our end device (e.g., PC, laptop, mobile phone). Following request is then send to the web server that initialize connection with particular streaming server where the specific video file is located, followed by video player activation.

Alongside the start-up phase we would like to outline the process of QoE prediction. It all starts with collection of statistical data. They are obtained from QoS measurements, where we collect data about condition of transition paths in our network. The condition is defined by the values of packet loss, bandwidth and delay. The second source of statistical data is the web browser itself, where we collect values of specific video parameter (e.g., resolution, bitrate, frame-rate, number of damaged packets). All which are stored in database server and consequently analyzed by our BN prediction model. Followed by final QoE prediction defined in probability of particular MOS. This whole evaluation phase is done in a loop until the last packet is received and the streaming session is terminated.

7. DISCUSSION/CONCLUSIONS

In this paper we outlined the actual state and different future challenges in the process of designing and assessing of QoE. This overview is mainly focused on assurance of sufficient level of user experience in the case of video delivery. The study specifies that during the designing phase one of the first and most important steps is to choose the right metric for quality evaluation. However, current techniques are not suitable for actual user requirements and evaluation of perceived video quality is inaccurate . Therefore, in the second part of this paper we came up with a new concept of QoE evaluation. Presented approach is based on the analysis of dependencies between user sensitivity to the changes of video quality attributes and perceived quality. This would be done by broad empirical study that would create an input to our prediction model.

As a next step we plan to extend our approach by objective assessment, which will help us to measure an amount of motion in video and resulting image degradation. Based on the predicted results we plan to implement real-time optimization of video streaming where we can identify application domain for our approach and priorities the actual running streaming connections.

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REFERENCES

[1] CROVELLA, M. – KRISHNAMURTHY, B.: *Internet Measurement, Infrastructure, Traffic and Applications*, John Wiley & Sons, Ltd., Chichester, 2006.

[2] ROMANIAK, P.: *Towards Realization of a Framework for Integrated Video Quality of Experience Asessment*, INFOCOM Workshops 2009, Rio de Janeiro, pp. 1-2, 2009.

[3] LIN, T. L. – KANUMURI, S. – ZHI, Y. – POOLE, D. – COSMAN, P. C. – REIBMAN, A. R.: *A Versatile Model for Packet Loss Visibility and its Application to Packet Prioritization*, IEEE Transactions on Image Processing, 19(3), pp. 722-735, 2010.

[4] ITU-R Recommendation BT.500-11: *Methodology for the Subjective Assessment of the Qualit of Television Pictures*, International Telecommunication Union, Geneva, Switzerland, 2002.

[5] P.910, I.T.R.: *Subjective Video Quality Assessment Methods for Multimedi Applications*, Recommendations of the ITU, Telecommunications Sector.

[6] CARNEC, M. – LE CALLET, P. – BARBA, D.: *Full Reference and Reduced Referenc Metrics for Image quality assessment*, Signal Processing and Its Application, pp. 477-480, 2003.

[7] WINKLER, S.: *Digital Video Quality - Vision Models and Metrics*, John Wiley & Sons, 2005.

[8] RUBINO, G – VARELA, M. – BONNIN, J. M.: *Controlling Multimedia QoS in the Future Home Network Using the PSQA Metric*, The Computer Journal, 49 (2), pp. 137-155, 2006.

[9] MENKOVSKI, V. – EXARCHAKOS, G. – LIOTTA, A. – SANCHEZ, A. C.: *Measuring Quality of Experience on a Commercial Mobile TV Platform* , 2010 Second International Conferences on Advances in Multimedia, pp. 33-38, 2010.

[10] YUEPING, Z. – SINGH, V. – YU GU – GUOFEI, J. – YU RU: *QoEScope: Adaptive IP Service Management for Heterogeneous Enterpris Networks*, IWQoS 2009, Charleston, pp. 1-5, 2009.

[11] CHODOREK, R. – LESCZUK, M.: *QoE Validation of a RSVP Protocol Extension Enabling Effi cient Resource Reservation for Aggregated Traf ic in Heterogeneous IP Networks*, QoMEX 2010, Trondheim, pp. 17-22, 2010.

[12] ITU-T P.800: *Methods for Subjective Determination of Transmission Quality*, International Telecommunication Union, Geneva, Switzerland, 1996.

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BIOGRAPHIES

Martin Kapa was born on 20. 07. 1984. In 2009 he graduated from a posgraduate program at the Department of Computers and Informatics on the Faculty of Electrical Engineering and Informatics at Technical University in Košice. He is currently a PhD candidate in the field of multimedia services a QoE evaluation.

František Jakab was born on 05. 08. 1959. He received the MSc. degree in Systemotechnic engineering from the St. Petersburg Electrotechnical Institute (Russia) in 1984 and the PhD. degree in 2005. He is employed as an assistant professor at the Dept. of Computers and Informatics, Technical university of Košice, Slovakia. He is a head of the Computer Engineering Group and Computer Networks Laboratory (http://www.cnl.tuke.sk). His research interests include projecting of computer network, modelling, simulation and network management, new form of multimedia-based communication, QoS, telelearning systems, intelligent tutoring systems. He has been a coordinator of several large international e-learning oriented projects supported by EC. He is a coordinator of the Cisco Networking Academy Program for the Slovak Republic and head of the Application Section of the Communication Technology Forum Association in Slovak Republic.